CHAPTER 1
GENERAL CONSIDERATIONS

SECTION I. INTRODUCTION

1-1. PURPOSE

The purpose of this manual is to provide information and guidance on the installation, operation, and maintenance of U.S. Army Central Boiler Plant equipment. Efficient plant operation becomes more important with each increase in the cost of fuel and equipment. The Central Plant operator has an important job in achieving and maintaining maximum efficiency of plant operation. The information and guidance in this manual should be reviewed as a first step toward achieving efficient plant operation.

1-2. CENTRAL BOILER PLANTS

The primary purpose of a Central Boiler Plant is to economically produce energy for distribution. This energy may be in the form of steam, hot water, or occasionally, compressed air or electric power. A distribution system is necessary to carry this energy to buildings, hospitals, kitchens, and laundries where it is used for heating, cooling, process, sterilization, and production of domestic hot water. Condensate or hot water is returned to the Central Boiler Plant where it is reheated in a boiler and returned to the distribution system for recycle.

a. Types of Central Boiler Plants. Energy for heating or process use is generally produced in one of five forms:

Low Temperature Water	LTW (up to 250° F, less than 160 psig)
Medium Temperature Water	MTW (251° F, to 350° F)
High Temperature Water	HTW (351° F to 450° F)
Low Pressure Steam	LPS (up to 15 psig)
High Pressure Steam	HPS (above 15 psig)

The type of Central Boiler Plant built depends upon the requirements of the specific installation. For applications involving only space heating and domestic water, a low temperature water plant is generally sufficient. If steam is required for large process loads or electric generation, a steam plant must be constructed. For most other installations, an economic evaluation must be performed to compare the costs of a high temperature water system to those of a steam system. Such an evaluation usually shows the high temperature water plant to be more economical. The following paragraphs provide a brief comparison of the major types of central heating plant systems.

b. Comparison of High Temperature Water and Steam. The major advantages of high and medium temperature water systems result from the closed-loop distribution system. The closed loop system recycles the unused energy in the water and results in very small system water losses. By comparison, steam distribution systems include condensate return systems with potentially significant energy and water losses due to steam flashing, defective traps, defective pressure reducing valves, pipe leaks, and unreturned process steam. The advantages of high and medium temperature water systems are further discussed in the following paragraphs.

(1)**Energy Losses from a Steam System.** Figures 1-1 and 1-2 illustrate the heat balance at a heat exchanger for 100 psig and 15 psig steam/condensate system, respectively. When 100 psig steam is supplied to a heat exchanger, the condensed water is at a temperature of 338° F and contains 26 percent of the energy originally supplied in the steam. When the condensate discharges from the trap, 13 percent of the water flashes to steam and the remaining condensate is at a temperature of 212° F. When 15 psig steam is supplied, the condensed water contains 19 percent of the original energy at a temperature of 250° F. When the condensate discharges from the trap, 4 percent of the water flashes to steam. The energy losses and makeup water requirements of the low pressure system are thus lower, making the low pressure system preferable if a steam system is used.

(2) **Pressure Reducing Valves and Vent Condensers.** The pressure reducing valve supplies the heat exchanger with low pressure steam, thus minimizing flash-losses. If a vent condenser is not supplied, the flash-off steam is lost. If a portion of the condensate is not returned to the central boiler plant for any reason, the portion of the energy remaining in the condensate is lost. For example, if a 100 psig system has 20 percent condensate loss, 5.2 percent (.20 x .26 = .052) of the total energy produced is wasted. In addition, 20 percent treated make-up water is needed to keep the system operating. Procedures for monitoring and controlling condensate losses are further discussed in paragraph 3-2.

(3) **Heat Balance for an HTW System.** Figure 1-3 illustrates a heat balance for a high temperature water system at a heat exchanger. It is informative to compare the high temperature water system with 100 psig steam system. In both cases, 1125 lbs of water is heated from 50° F to 140° F by the heat exchanger. The high temperature

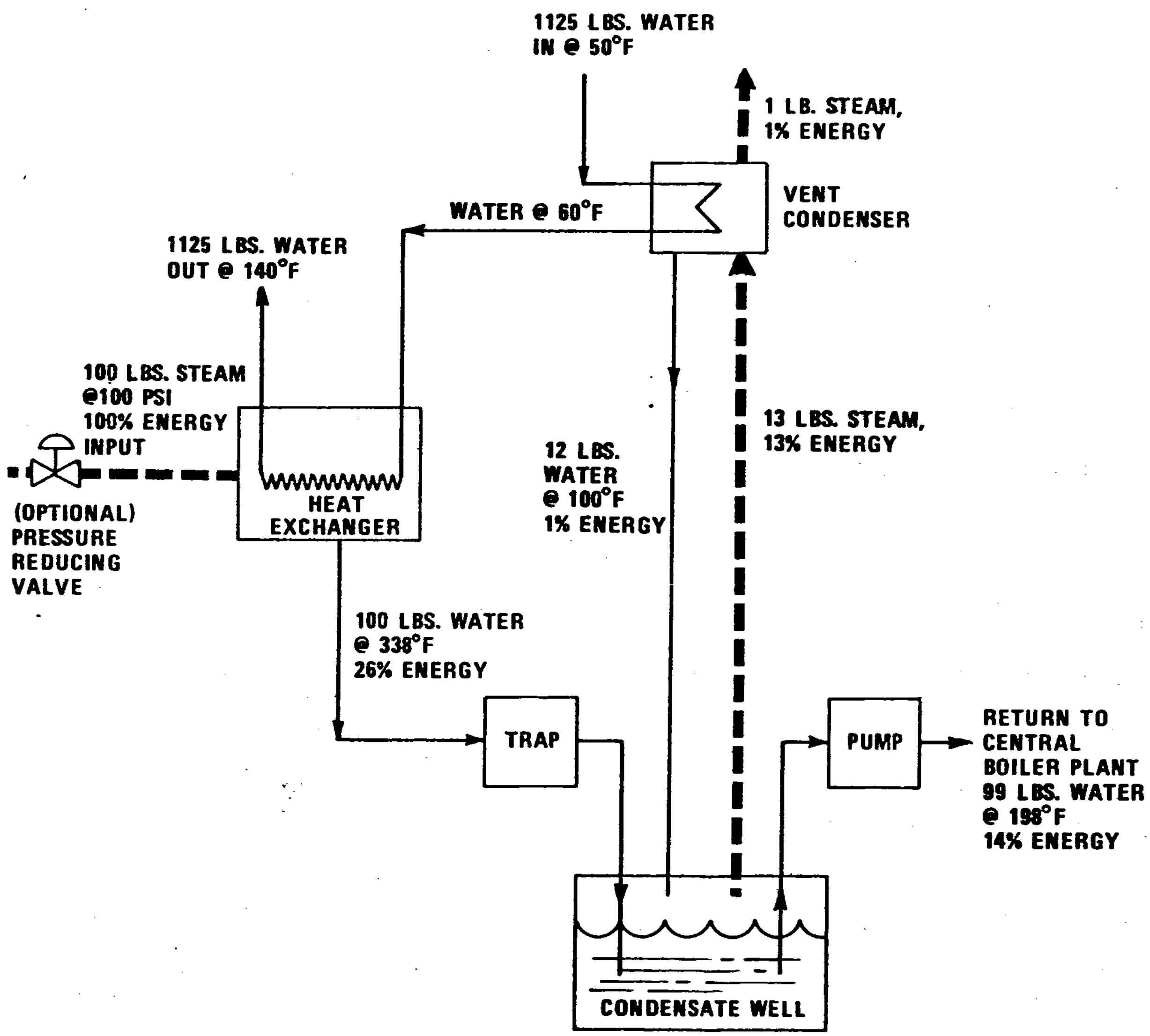

FIGURE 1–1. 100 PSI STEAM HEAT BALANCE

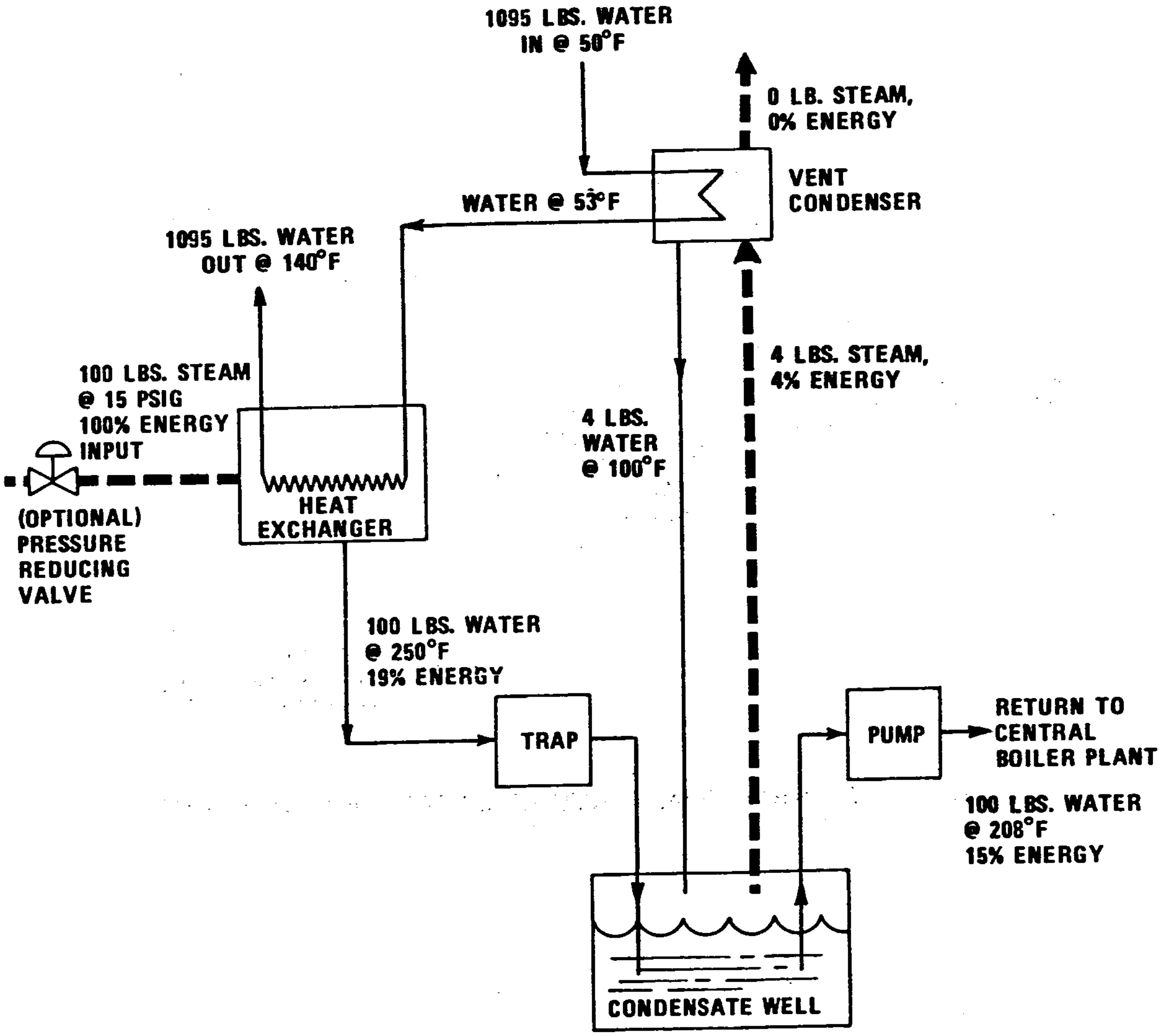

FIGURE 1–2. 15 PSI STEAM HEAT BALANCE

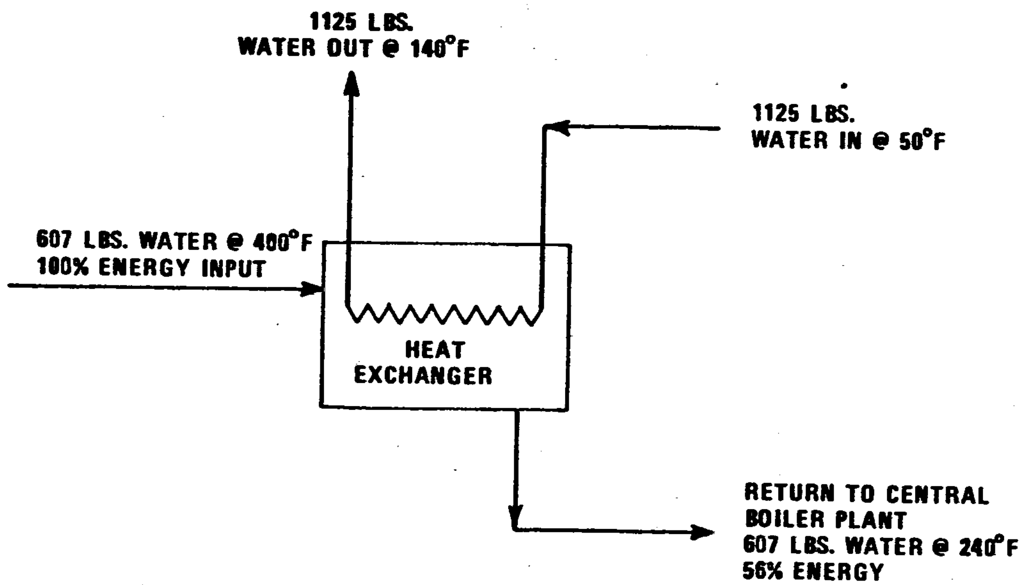

FIGURE 1–3. HIGH TEMPERATURE WATER HEAT BALANCE

water system returns 56 percent of the energy input to the heat exchanger while the steam system returns 14 percent. The high temperature water system does not have steam flashing losses or condensate losses. The HTW system is clearly a more efficient means of distributing energy from a central boiler plant, if the process requirements of the system are such that it is applicable. Appendix C provides Heat Balance Calculations explaining these numbers.

(4) **Corrosion.** A major advantage of the high temperature water closed-loop distribution system is an inherent reduction in distribution system corrosion as compared to steam/condensate distribution systems. Maintenance, pipe replacement, and energy costs associated with line leaks are thereby reduced, resulting in a significant savings.

(5) Stored Thermal Energy. The large amount of stored thermal energy in an HTW and MTW distribution system allows for more effective response to short-duration peak load requirements. Boiler load swings are reduced, and more accurate combustion control is possible. HTW and MTW plants are generally sized for peak loads 10 to 20 percent less than steam plants because of the stored thermal capacity in the system.

(6) **Safety.** High and medium temperature water systems are safer than steam. In the event of a line rupture, the stored thermal energy in the water is dissipated by accelerating the water to higher velocities and flashing it to steam. A fine spray of 180° F water occurs, ending one to two feet from the rupture. The amount of energy exiting a ruptured high temperature water line is only 5 to 10 percent of the energy exiting a ruptured steam line of the same size.

(7) **Water Treatment.** Due to the low makeup water requirements, the capacity of a water treatment system for an HTW and MTW plant is a small fraction of that required for a steam plant. This provides a cost savings in equipment, maintenance, and chemical use requirements. Steam plants require more complex water treatment systems including a deaerator (not required in HTW or MTW plants) to provide oxygen-free water. If not carefully controlled, the deaerator can vent steam, resulting in energy losses. Steam boilers also require blowdown to maintain acceptable water quality, which contributes to makeup water requirements and plant energy losses. Blowdown is less or not required at all in a hot water boiler.

(8) **Loss of Steam Pressure and Quality.** If the distribution lines are long, significant reductions in steam pressure and quality (100% quality = 100% steam, 90% quality = 90% steam and 10% liquid water, etc.) can occur due to line friction and heat losses.

c. Low Temperature Water. Low temperature water plants have all the basic advantages of HTW and MTW plants relative to steam plants. In addition, the lower system pressure associated with LTW provides a cost advantage due to the lower pressure ratings required for boilers, accessories, and piping. However, LTW plants cannot provide energy at temperatures required for many process, hospital, and laundry applications, thus eliminating them from consideration for many installations.

1-3. EQUIPMENT

A Central Boiler Plant is comprised of ten major categories of equipment, as described below.

a. Heat-Absorbing Equipment. Heat (energy) from the combustion of fuel is transferred to the boiler water to generate steam or hot water in the furnace and generating sections of the boiler. Economizers are sometimes provided to recover heat from the boiler flue gases (products of combustion) and transfer it to the feedwater. Heat from the flue gases can also be absorbed by air heatings for transfer to the combustion air before it enters the furnace through the burner or stoker grate. Plant efficiency is closely related to the ability of the boiler, economizer, or air heater to absorb heat from the products of combustion.

b. Fuel-Handling Equipment. Coal-burning plants require facilities for storage of coal, and equipment for moving the coal to storage and reclaiming and transferring it at the boiler. Provisions are usually made to move the coal directly from the delivery point to the boiler. Mechanical, pneumatic, or hydraulic ash removal systems are necessary in coal-burning plants to dispose of ash from the boiler, stoker, and dust collector hoppers. Oil-burning plants require one or more oil-storage tanks with associated transfer pumps, tank heaters, connecting piping, tank lever meters, flow meters, and day tanks. Pumping equipment and piping to the burners will be required and oil heaters may be required depending upon the oil used. Ash removal equipment may be required in some cases. Gas-burning plants will have a gas pressure reducing station (shut-off valve, strainer, pressure reducing valve, safety-relief valve, and gas meter) to reduce the incoming line pressure required in the distribution piping and burners.

c. Combustion Equipment. Combustion equipment for oil and gas firing consists of safety shut-off valves, safety devices or interlocks, control valves, and burner(s). The function of the burner is to ignite and burn the fuel by efficiently and completely mixing it with combustion air in the furnace. Coal may be fired manually on grates or automatically by stokers, or burned in suspension in a pulverized furnace or fluidized bed.

d. Air-Handling Equipment. In order to achieve efficient combustion of fuel, the amount of air delivered to the burner or stoker must be properly matched to the amount of fuel. Forced draft fans with associated control dampers are used to provide combustion air. Overfire air and reinjection fans for stokers and primary air fans for pulverizers may also be required. Induced draft fans are used to pull the flue gas from the furnance through the boiler bank and any ductwork, economizer, air heater, or dust collector provided.

e. Controls and Instrumentation. Since operator safety and protection of the boiler are of great importance, boiler feedwater controls and burner safety controls are required to guard against failures due to low boiler water or explosion. Combustion controls regulate the fuel and air flow to maintain efficient combustion. The high price of boiler fuel which justifies improved combustion controls also justifies the use of recorders and meters to monitor combustion and ensure optimum plant operation.

f. Pollution Control Equipment. The combustion of fuel may generate a variety of pollutants in excess of limits set by regulatory agencies. The major pollutant emissions of present concern are particulate, oxides of sulfur (SOx), and oxides of nitrogen (NOx). The use of a fuel lower in ash or surfur content and modifications to the combustion process can be effective in reducing these emissions. If these fuels are too expensive or combustion modifications only partially effective, pollution control systems can also be used to bring emissions within acceptabe limits. Typical pollution control systems are mechanical collectors, fabric filters, electrostatic precipitators, wet scrubbers, and tall stacks.

g. Water Treatment Systems. Proper water treatment prevents scale formation on the internal surfaces of the boiler and reduces boiler and distribution system corrosion. Water treatment often involves a combination of external and internal techniques. External water treatment includes removal of suspended matter with clarifiers and filters; reduction of water hardness with lime or zeolite softeners or demineralizers; and reduction of corrosive gases with deaerators. Internal water treatment involves injection of chemicals directly into the boiler to control any impurities remaining after external treatment chemicals include caustic to aid precipitation, phosphate for hardness removal, and dispersants to aid precipitate removal by blowdown. Specific equipment is also required for boiler blowdown systems and testing purposes to monitor and maintain a functional water treatment system.

h. Water Supply Equipment. Feedwater is supplied to steam boilers by means of centrifugal or reciprocating pumps. Centrifugal pumps are also typically used to circulate water through high temperature water boilers and their associated distribution systems.

i. Distribution Systems. The energy produced in the central boiler plant, whether in the form of steam or hot water, must be transferred to other buildings through a distribution system. The distribution system also returns unused energy in the form of hot water or condensate to the central plant for recycle. The distribution system consists of insulated, weatherproof pipelines, valve pumps, regulators, and heat exchangers. Steam systems also include traps and condensate handling of equipment.

j. Miscellaneous. Each central boiler plant has its own unique set of maintenance tools and spare parts inventory. Also unique to a given plant is its electric power distribution system, air compressors, and emergency generator sets.

SECTION II. ELEMENTARY COMBUSTION PRINCIPLES

1-4. FOSSIL FUELS

Fossil fuels are derived from the remains of plant and animal organisms. These organisms used carbon dioxide (CO_2), minerals, water, and energy from sunlight to grow. Over millions of years this material accumulated and the original carbohydrates and other organic materials were buried and converted to the hydrocarbon or fossil fuels we use today. These fossil fuels are found in solid, liquid, and gaseous form.

a. Coal. Coal is a solid fossil fuel. Coal's characteristics are directly affected by its age, since the plant matter from which it was formed first changes to peat, then with sufficient heat, pressure, and time to brown coal or lignite, subbituminous coal, bituminous coal, and finally anthracite — the oldest of coals. If anthracite were submitted to additional pressure and heat, graphite and eventually diamonds would be produced. Considering the cost of coal today, it is worth thinking of coal as young diamonds.

(1) In the United States, lignite is found primarily in North Dakota, Montana, and Texas, with proven reserves of 447 billion tons. Subbituminous coal is found in Montana, Wyoming, Washington, and Alaska with proven reserves of 437 billion tons. Bituminous coal is found in at least twent-eight states with proven reserves of over 800 billion tons. Anthracite is found in Pennsylvania, Alaska, Arkansas, and Virginia with proven reserves of 25 billion tons. Because of its widespread availability and subsequently lower transportation costs, bituminous coal is most frequently used. Table 1-1 outlines the classification of coals as given by ASTM D 388. This standard establishes ranges for fixed carbon, volatile matter, and heating value for each class and group of coals.

(2) Coal is a highly complex fuel. Most of its heating value exists in the form of carbon, which is present